

PLANNING, MANAGEMENT, OPERATION AND MAINTENANCE OF DESALINATION PLANTS

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1. Planning a Desalination Project

Improvement in living standards, together with increased industrial and agricultural development, cannot take place without the availability of adequate supplies of bacteriologically pure, low salinity water. Throughout the world, the increasing shortage of good quality fresh water is resulting in a greater recognition of the need for desalination of sea and brackish waters, although some governments and water utilities are slow in accepting this solution to their problems. This may be due to the unfamiliar technology, lack of expertise and high cost estimates.

There is no mystique to the success of the various desalination processes. Three basic factors are directly related to and responsible for the success of any desalination operation:

1. The conservative selection of well proven construction materials that are suitable for the ambient conditions. Selection of these materials must take into consideration any inherent corrosive nature of the environment, the general feed water characteristics and any adverse conditions that are relevant to the particular site and which might affect the performance of the materials selected.
2. Selection of the most appropriate desalination process, which may be either a membrane or a distillation system. The process must be optimal for the ambient conditions and the product water characteristics required. The choice of energy source must be appropriate for the location and the process. This may include waste heat from a power station or industrial process, or mechanical or electrical energy.

In the case of distillation processes it is vital to make the right selection of design criteria that involves conservative temperatures and heat flux rates, fluid velocities and flow rates. In the case of membrane processes it is important to select adequate pre-treatment regimes that are appropriate for the specific feed water characteristics and to ensure the application of conservative operating pressures and fluid transfer rates to maximize membrane life. The use of energy recovery systems wherever possible is also economically important.

1. Strict adherence to detailed Operation and Maintenance Procedures by well trained and experienced plant operators and maintenance technicians. The implementation of dedicated maintenance regimes involving both scheduled and preventive maintenance programs reduces the possibility of plant breakdown and improves the economy of operation.

Adherence to these three principles should ensure the success of the selected plant by providing the optimum economical life of the equipment together with the lowest possible plant operating costs commensurate with the locality, energy costs and other inherent physical and financial conditions.

The maximum plant availability that may be expected under optimum operating conditions cannot exceed 8000 h per annum. The remaining 760 h of the year are required for scheduled maintenance of the equipment.

In the case of older facilities, when material failure and breakdown will naturally become more frequent, a lower availability figure, in the range of 7500 h, may be more realistic. When calculating the design capacity of any desalination facility, this figure should be taken into account and the plant should be sized accordingly. A useful 'rule of thumb' is that the maximum design capacity of a plant should be in the order of 118 per cent of the firm production capacity required.

There are three principal kinds of water requirement which are best met through desalination:

- A.** A requirement for relatively small quantities of high purity water. This might be to provide high purity water for boiler make-up, the nuclear industry, manufacture of computer chips, the pharmaceutical industry, various medical procedures, dialysis procedures or other specialized applications. Desalination facilities to produce such high purity water usually involve the distillation process with additional reflux stages in order to provide the necessary level of purity. Alternatively, the reverse osmosis process may be used in conjunction with an ion exchange polishing system. For these requirements the owner would normally expect to operate the desalination facility as an integral part of his production facility.
- B.** A requirement for small quantities of potable water for industrial use, hotel services and small residential areas. Under these conditions package desalination plants will provide adequate supplies of desalinated water with the required characteristics of low salinity and high bacteriological purity. The equipment used in these cases would normally involve either package reverse osmosis units or, if waste heat from power generation or an industrial process is available, it could be appropriate to use a package evaporative system. This could be either multi-effect (MED), thermal vapour compression (TVC) or multi-stage flash evaporation (MSF). The owner may operate the facility with his own personnel, or it may be appropriate to employ a contractor that would take full responsibility for the management, operation and maintenance of the facility on the basis of a fixed price, long term contract.
- C.** A requirement for large volumes of potable water for municipal water supply schemes. The desalination facilities would comprise large scale plants using multi-stage flash, multi-effect, or thermal vapour compression, in conjunction with a supply of low grade thermal energy (e.g. from a power station or solid waste incineration facility). Where only prime electrical or mechanical energy is available, reverse osmosis is the process of choice.

Such large scale desalination facilities may be single purpose or, alternatively, the desalination plant may form part of a dual purpose or combined cycle facility where the desalination section utilizes the waste heat from power generation or an industrial process. Wherever large volumes of low grade waste heat are available, the evaporative processes would normally be selected in preference to membrane processes.

The management, operation and maintenance of the facilities in "B" and "C" above may be carried out in a number of ways:

The plant may be owned and operated by the end user of the water or power. The owner of the facility may choose to operate the plant with his own personnel. Alternatively, the owner may employ the services of a specialist operation and maintenance contractor to run the plant for a specific period at a fixed, contractually agreed price. Such a contract may also include an option to train the owner's personnel so that they are able to replace the contractor's personnel either en block at the end of the contract period or gradually throughout the term of the contract.

Alternatively, the water and/or power required may be purchased by the end user from a private company or from a contractor that owns and operates the desalination and/or package power plant. This system has increased in popularity in recent years.

A reliable source of bacteriologically pure, low salinity water may be required by an organization for its own in-house use. The organization may be involved in either the tourist trade, hotel or leisure park management, in general manufacturing, in high-tech science products, oil production, in the petrochemical fields or supply bunkering water for a major port. Local conditions may dictate that adequate quantities and quality of water are not available from external sources for the successful operation of these various industries.

In coastal areas, a contractor can locate barge-mounted desalination and power generation facilities at convenient locations on the shoreline. These facilities can deliver desalinated water and electrical power to the client's terminal points. At the end of the supply contract period the barges can be refloated and moved to other locations. Land based package plants can be handled in a similar manner, although removal from the site at the end of the supply contract is more complicated and may entail the sale of the equipment to the client.

The end users are able to obtain all their water and power requirements without having to provide the initial capital for purchase of the equipment, or for taking responsibility for supplying the water. The fact that the plant can be removed at the end of the contract and utilized elsewhere means that the capital cost need not be totally carried by the initial contract. Consequently, the unit cost of power and water on such a supply contract may be considerably less than would otherwise be the case.

In both the above cases the management, operation and maintenance of the desalination and/or power generation facilities may be carried out contractually for the plant owner by an independent, specialist contractor. In "B" above, where water is a utility requirement, rather than the main product of the owner's facility, the plant management rarely wish to add operation of a water plant to their other responsibilities. In such circumstances, they may prefer to purchase the water required from a privately owned desalination plant, leaving the responsibility for water supply to others. Alternatively they may decide to install their own desalination facility and employ a contractor to take full responsibility for running the plant on their behalf.

In "C" above, the plant is often government or municipality owned and operated, but the trend is now towards contractual management, operation and maintenance services. As government and municipal funding has become subjected to tighter constraints, there is

has been a worldwide tendency for major plants to be constructed either directly under private ownership or on build, own, operate and transfer (BOOT) schemes. In the former case, the private sector plant owner would own and operate the facility, selling the water or power/water to the various distributing authorities or directly to consumers under long term, fixed price contracts. In the latter case, the BOOT contractors would build, own and operate the facility and then, after a specified period, the ownership of the plant would be transferred to the client. Payment for the plant and its operation would be factored into the unit cost of power sold to the client.

1.1. Personnel Skills

In addition to the general management and administrative skills necessary for the day to day operation of any major facility, the various desalination processes involve a broad spectrum of scientific and engineering technologies complemented by a number of trade crafts required for on-going operation and maintenance. It is vital that the personnel have sufficient theoretical and practical knowledge of chemical and physical sciences, as well as mechanical, electrical and chemical engineering, for the diagnostic control, chemical conditioning and general operation of the various processes.

Successful operation and maintenance of desalination facilities requires skilled mechanics, pump fitters, electricians, instrument technicians, electronic technicians and computer programmers to operate and maintain the equipment and the sophisticated control systems and computerized recorders and controllers. Present day "state of the art" desalination is a highly specialized and constantly expanding field, and the availability of qualified and experience engineers, technicians and specialists with in-depth knowledge and relevant skills is extremely limited.

It is therefore of particular importance for any major desalination facility owner or operator to include a comprehensive training program to train new employees and to upgrade the skills of existing personnel. Such training may be in-house with company-employed instructors, by contractual arrangement with specialist training organizations, or a combination of both these options.

A typical combination program would include in-house training comprising practical work, theoretical classroom lectures and "on-the-job" training under the supervision of professional instructors and qualified working engineers and technicians. Theoretical training for engineers and chemists would be accomplished by external degree or diploma courses operated by either universities or technical colleges. A typical example being the Master Degree Course in Desalination founded by the late Professor Silver at Glasgow University.

1.2. Choice of Owner-operation or Contractual Management Services

The owners of a dedicated water or power/water production facility may prefer to employ their own personnel to operate the plant directly under the direct responsibility of their own management. In such circumstances, many problems have to be overcome. The management personnel must have an in-depth knowledge of desalination plant operation. They will need to recruit capable staff with adequate experience and knowledge of the operation and maintenance of the particular desalination equipment

and process. It is not an easy task to locate, identify and employ people with such skills and experience. The most competent personnel are already employed in long term, permanent positions with excellent prospects for advancement. They can only be wooed from their current employment positions by offers of improved conditions, promotion and financial inducements. This situation automatically leads to escalating operating cost for plant owners or operators.

The obvious solution is for the operating entity to train its own personnel. This requires a long term commitment to training with considerable investment in training courses, equipment and instructors. Few single plant owners have the necessary historical association with desalination to have such skills available. Consequently, there is considerable advantage to be gained, in the short term at least, in the employment of a professional operating company with the necessary qualified and experienced personnel.

Sub-letting the contractual management, operation and maintenance of desalination facilities to a contractor has a number of advantages to the employer. These include:

- A.** Competitive tendering for the management, operation and maintenance services ensures that operational costs are maintained at a minimum level. Periodic re-tendering of these services on the open market ensures that operating costs are maintained at the most competitive market rates for specific contract periods.
- B.** The availability of contractually fixed operating costs simplifies the client's financial planning, enabling accurate financial forecasting and future planning. The manufacturing and operating cost of a business can thus be retained within strict budgetary limits.
- C.** The plant owner is absolved from the responsibilities and risks of plant breakdown and failure. Under the terms of the management and operation contract, the contractor and his insurers accept full responsibility for such problems under the performance penalties in their contract with the plant owner.
- D.** The contractor will guarantee the availability, productivity and product water quality in accordance with the manufacturer's design parameters. Stringent contract conditions, including financial penalties for below-standard performance, the provision of third party, personnel and machinery breakdown insurance, and cover for damage incurred due to operator error etc., will ensure that the plant owner is completely absolved from the overall responsibility and risks involved in operating the plant and equipment.
- E.** Under the terms of the management and operation contract, the contractor is required to operate and maintain the facility in an optimum manner throughout the term of the contract, at minimum cost to the owner.
- F.** Although it may not be practical in all circumstances, in cases of breakdown or emergency conditions, the contractor might be required to continue to supply water by whatever means possible if the plant has not been repaired within a stated minimum period.

These stringent operating and maintenance specifications, detailed within the tender documents, warrant that the required high standards of operation and maintenance are implemented at all times. This ensures that throughout the economic life of the plant, the maximum availability and optimum performance of the equipment will be achieved. Upon expiry of the contract term, the plant must be returned to the custody of the owner in a pristine condition; allowing for normal wear and tear and the expected deterioration of the facility due to age.

Typical contract periods are for either 3, 5 or 10 year periods. The 5 year contract is the most common of these. Longer contract periods tend to be uneconomical, due to the need to include large contingencies to allow for any unforeseen inflationary factors that might occur during the life of the contract. Conversely, mobilization costs in short term contracts tend to be disproportionately high and consequently distort the overall operating costs.

In general terms, the contractor is required to operate the client's equipment in strict conformity with the manufacturer's operating and maintenance procedures. These may be supplemented with special procedures dictated either by local ambient conditions or the operator's specialized experience.

Whether the plant is operated by a contractor or by the owner's own personnel, maintenance should be carried out strictly in accordance with the plant manufacturer's detailed equipment-specific procedures, approved by the equipment supplier.

Detailed historical records should be kept and regularly maintained for each major item of equipment. Such records should include:

- A description of all work carried out for each item of equipment.
- A list of parts repaired, removed and replaced.
- Details of the maintenance time involvement.
- Details of the names of personnel carrying out the work.
- Historical costs of maintenance and services. This information will be invaluable in the selection of future equipment.
- Revised "as built" drawings, if structure or layouts are modified.

In addition to scheduled maintenance services, a regime of preventive maintenance should be implemented. This preventive maintenance service provides unscheduled repairs and general on-going refurbishment activities, painting etc., on an as-required basis throughout the facility. Historical experience indicates that a comprehensive preventive maintenance service will dramatically reduce the requirement for breakdown maintenance and substantially increase the availability of the plant.

The operation and maintenance contractor will be responsible for procuring all the day-to-day consumables required for operation of the facility as part of his overall contractual responsibilities. In addition, the provision of all spare parts, fuels and bulk chemicals may be included within the fixed contract price. Alternatively, the contractor may procure these consumables on a reimbursable basis after obtaining purchasing approval from the client.

The contractor should be required to pay particular attention to safety procedures in order to ensure both the safety of the equipment and his personnel. The operating procedures should ensure that a strict code of safety practice is applied at all times for any operational or maintenance activity throughout the facility. All operating and maintenance personnel should be provided with safety clothing and protective overalls, helmets, shoes, gloves and where necessary eye wear, face masks and respirators. Protective clothing should be worn at all times by personnel on duty or entering the operational sections of the facility.

A "Permit to Work" procedure should be inaugurated immediately the plant is commissioned and fully implemented prior to any work being carried out on high temperature, pressure or high voltage systems.

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